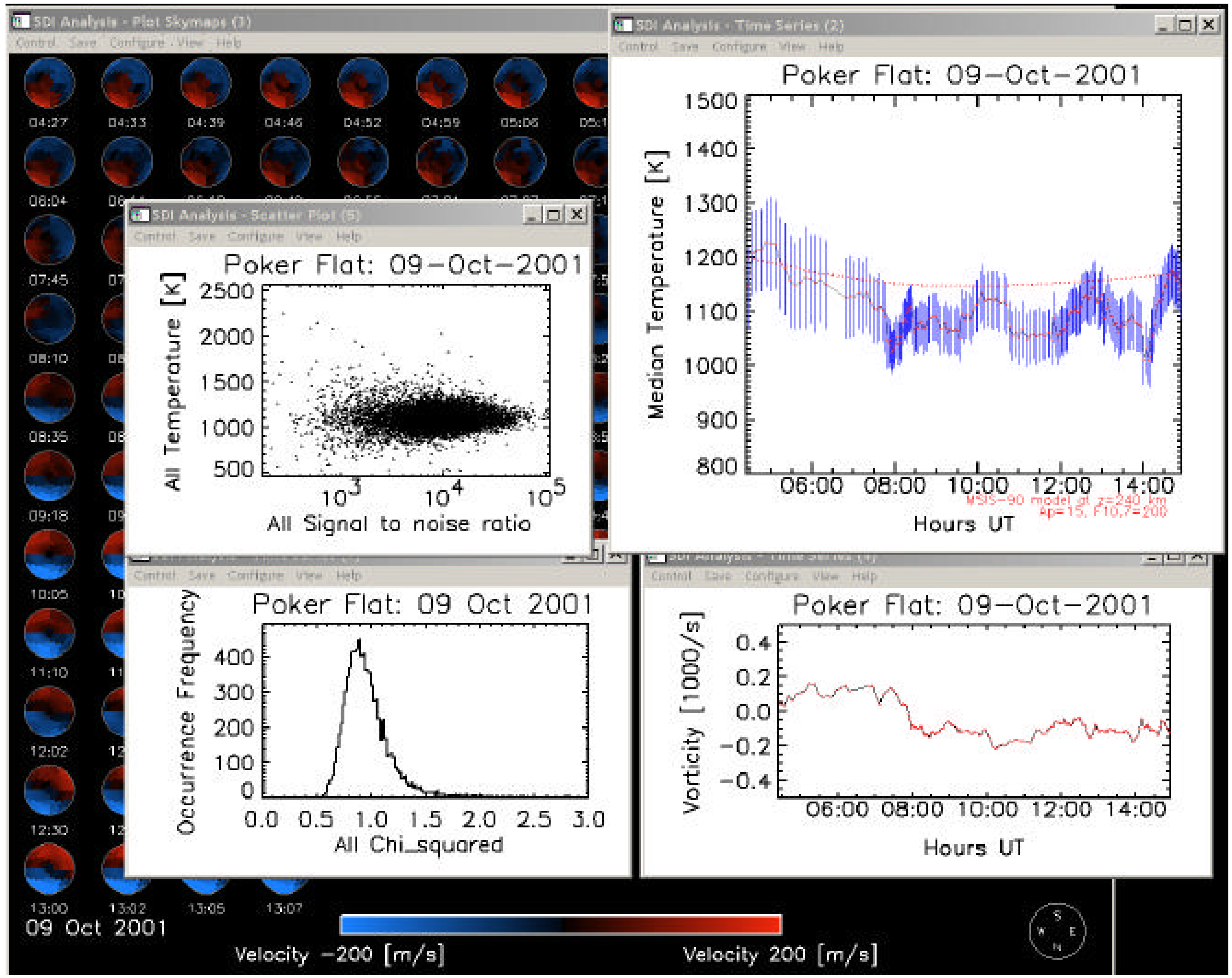
Some Future Challenges For Ground-Based Optical Aeronomy



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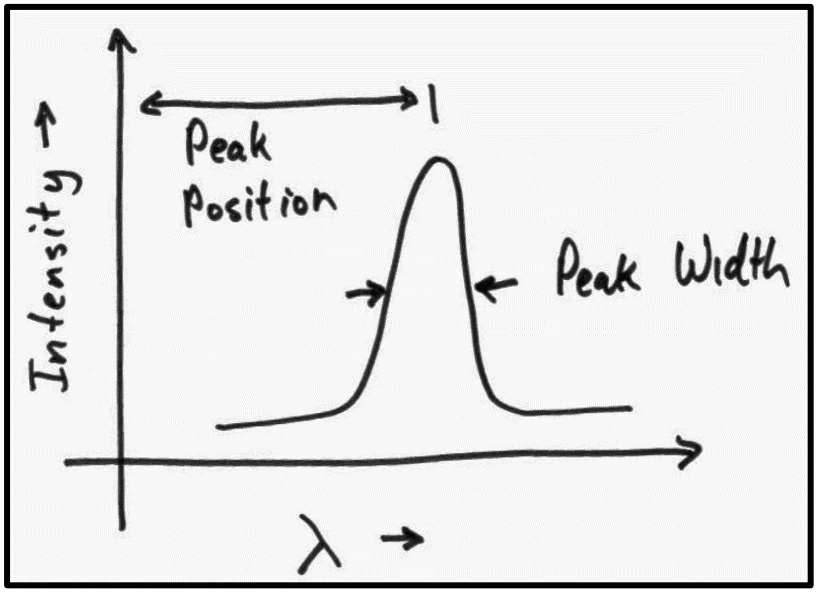
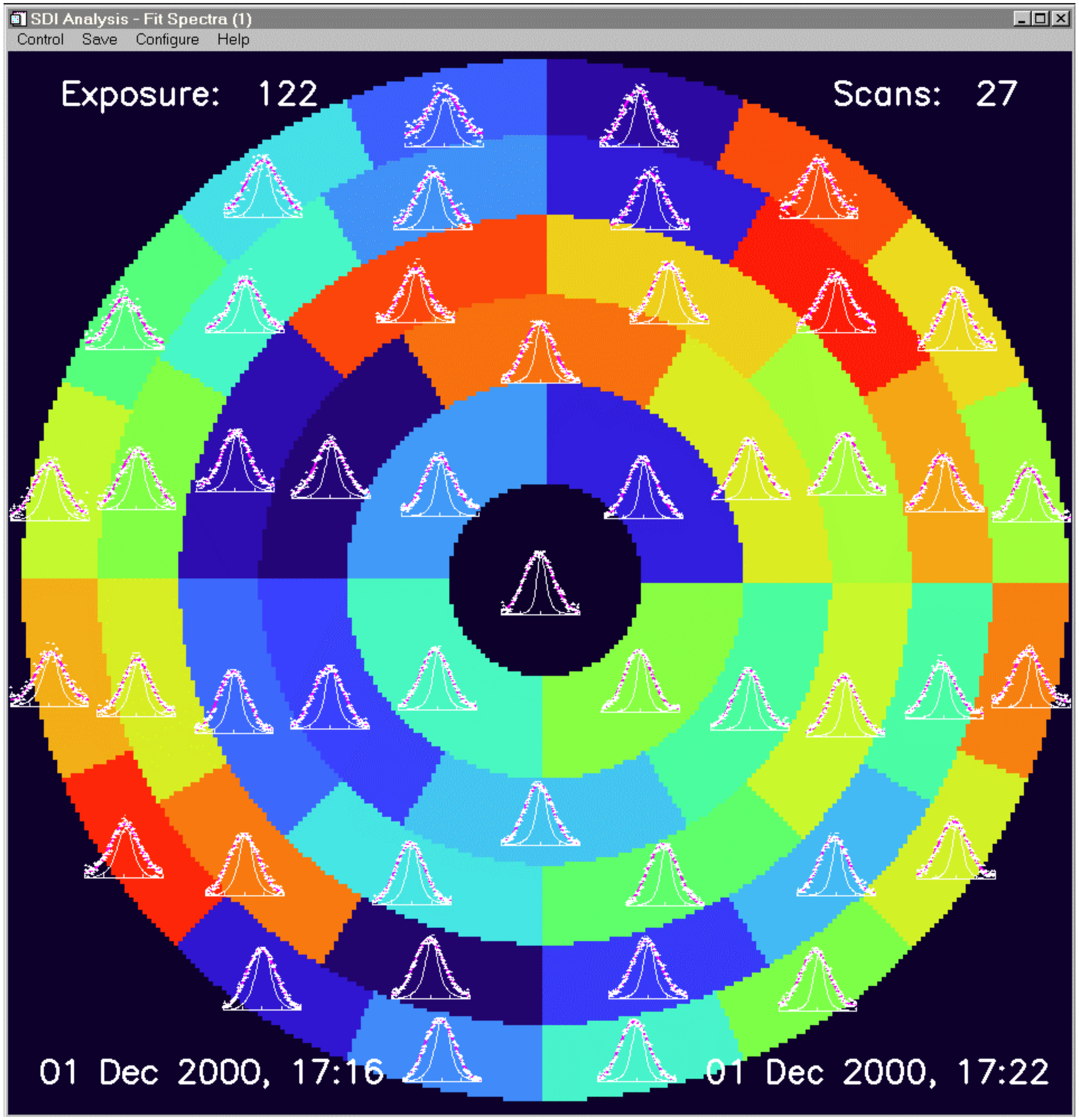
High-resolution line spectra



- To derive upper atmospheric winds and temperatures we record spectra of an optical emission line originating from the height of interest.
- We then fit a curve to the emission spectrum, to yield estimates of peak intensity, position, and width.
- The fitted peak position gives an estimate of the line-of-sight wind, whereas the fitted width can be used to estimate temperature.



Spectral Imaging

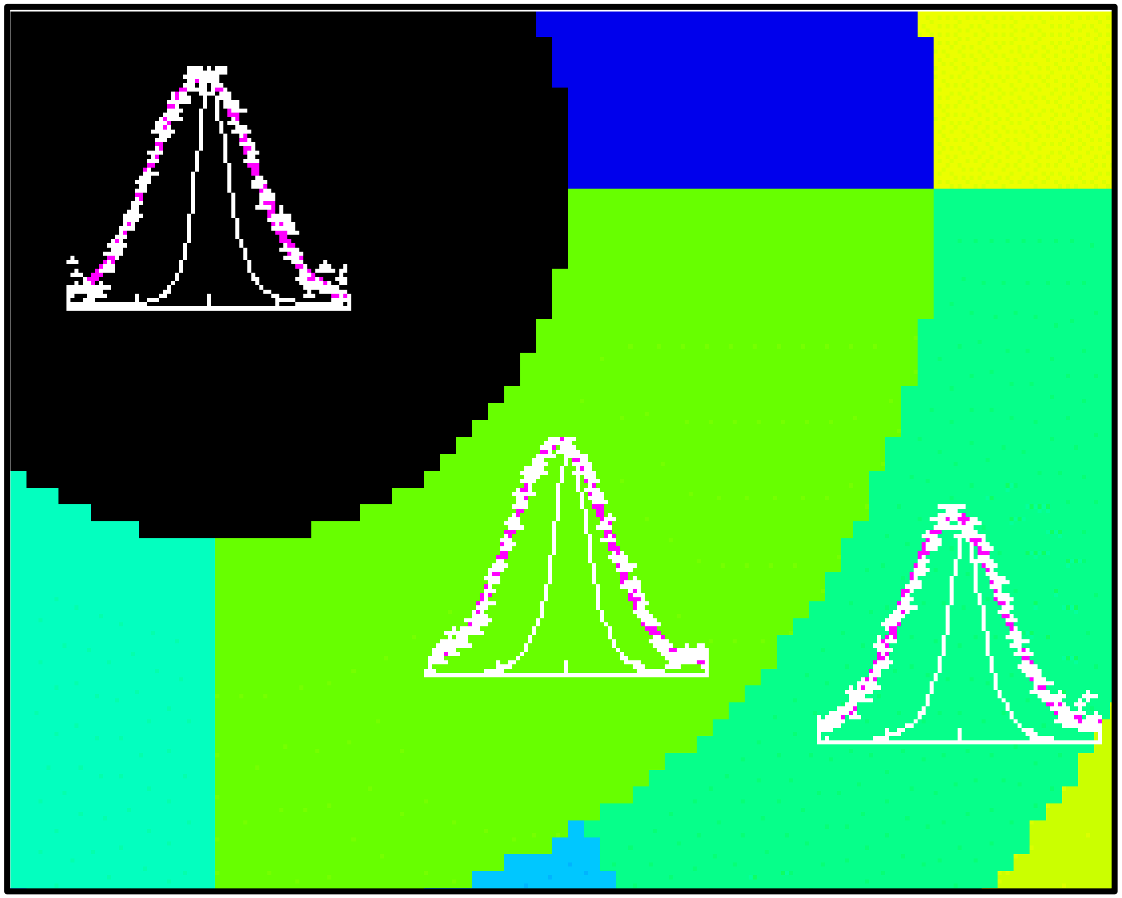
- A ground-based spectrometer can measure how the emission spectrum changes with look-angle across the sky.
- Because of the viewing geometry, there is no incentive to do this with high angular resolution.
- Rather, we sum sets of adjacent pixels' spectra into "zones".

A closer look at the spectra

The previous plot showed 3 types of spectral curves:

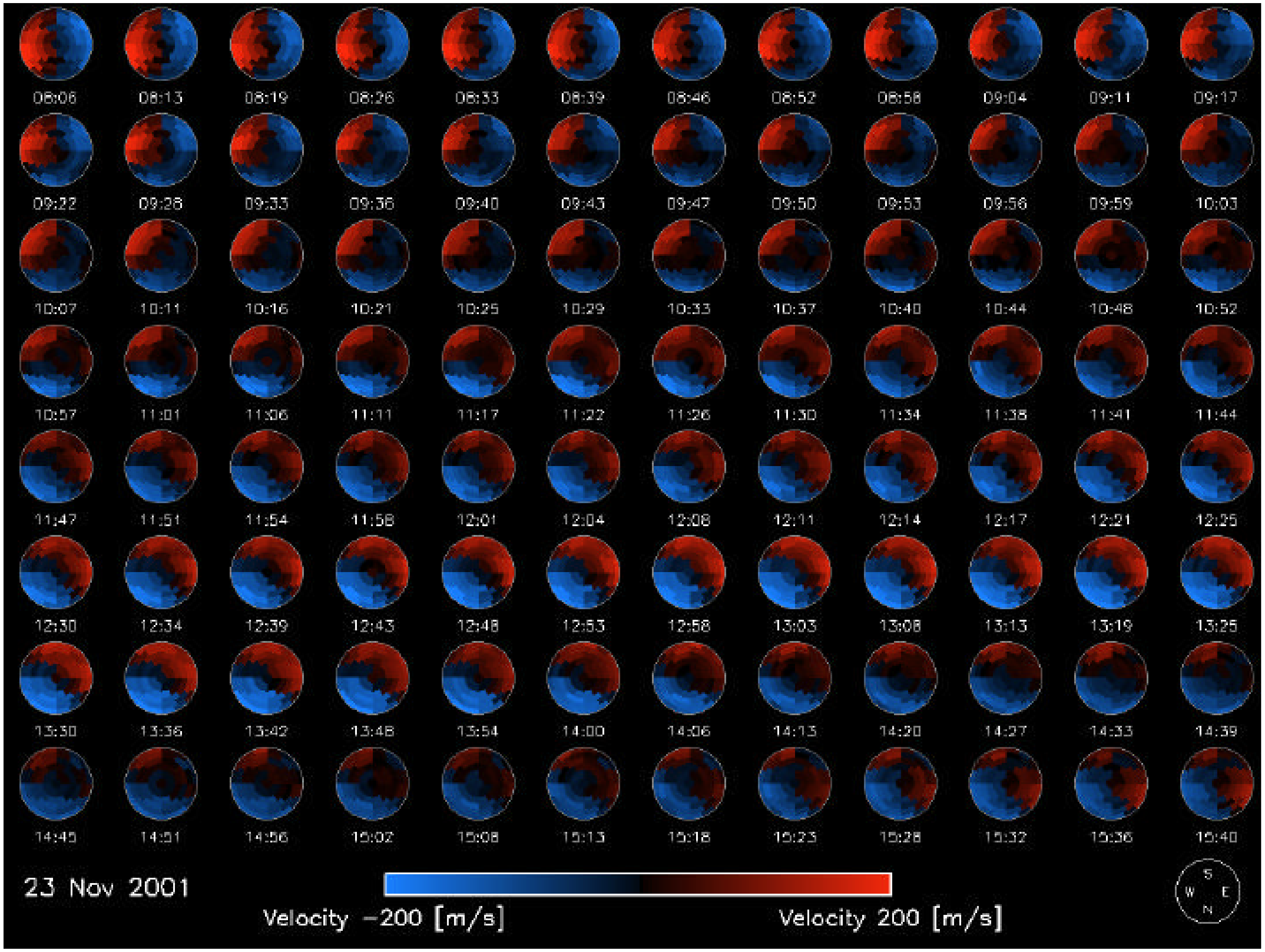
- The observed 630 nm sky spectrum (white crosses)
- A fitted model sky spectrum (magenta curve)
- The spectrum of a HeNe laser recorded in the corresponding zone.

Clearly, the sky spectrum is broader than the laser spectrum, indicating the instrument's ability to resolve temperature broadening.



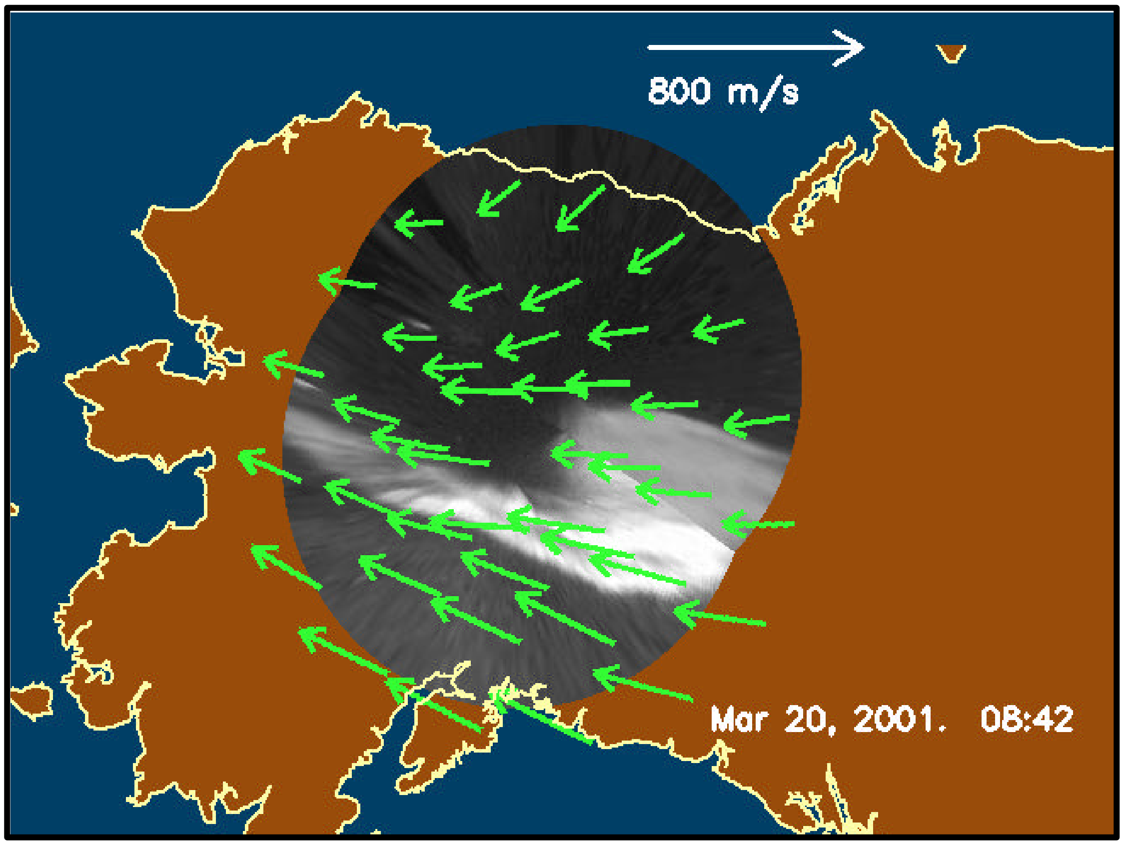
Line-of-Sight Wind Mapping

Line-of-sight winds (shown here using a blue-to-red color code) derived from Doppler shift measurements taken across the sky.



Inferring Horizontal Wind Vectors

Doppler imaging only directly measures line-of-sight wind components. We infer the underlying vector field by fitting a model of the form:



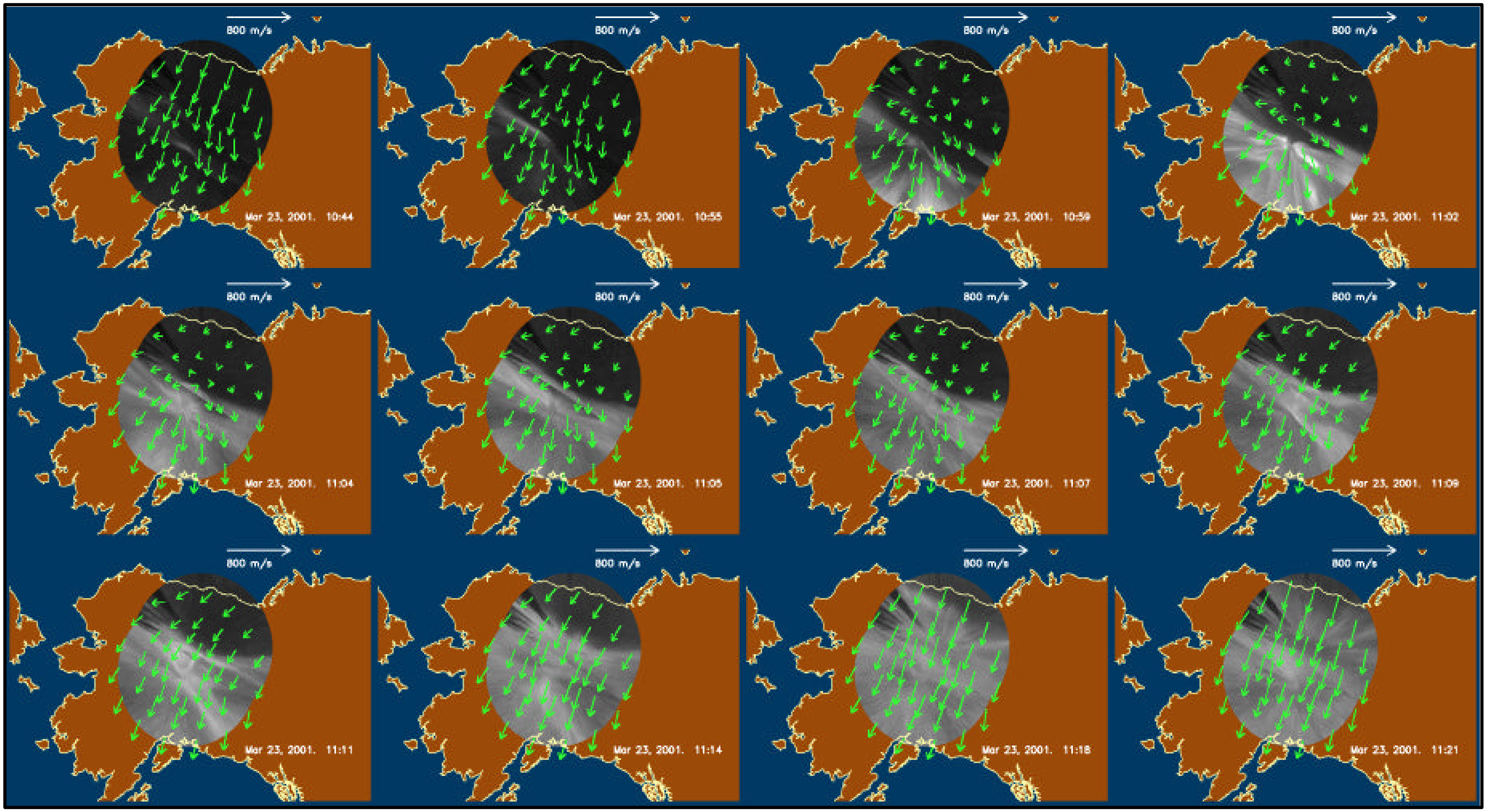
$$H_x = u_0 + x\,\partial u/\partial x + y\,\partial u/\partial y$$

$$H_y = v_0 + x\,\partial v/\partial x + y\,\partial v/\partial y$$

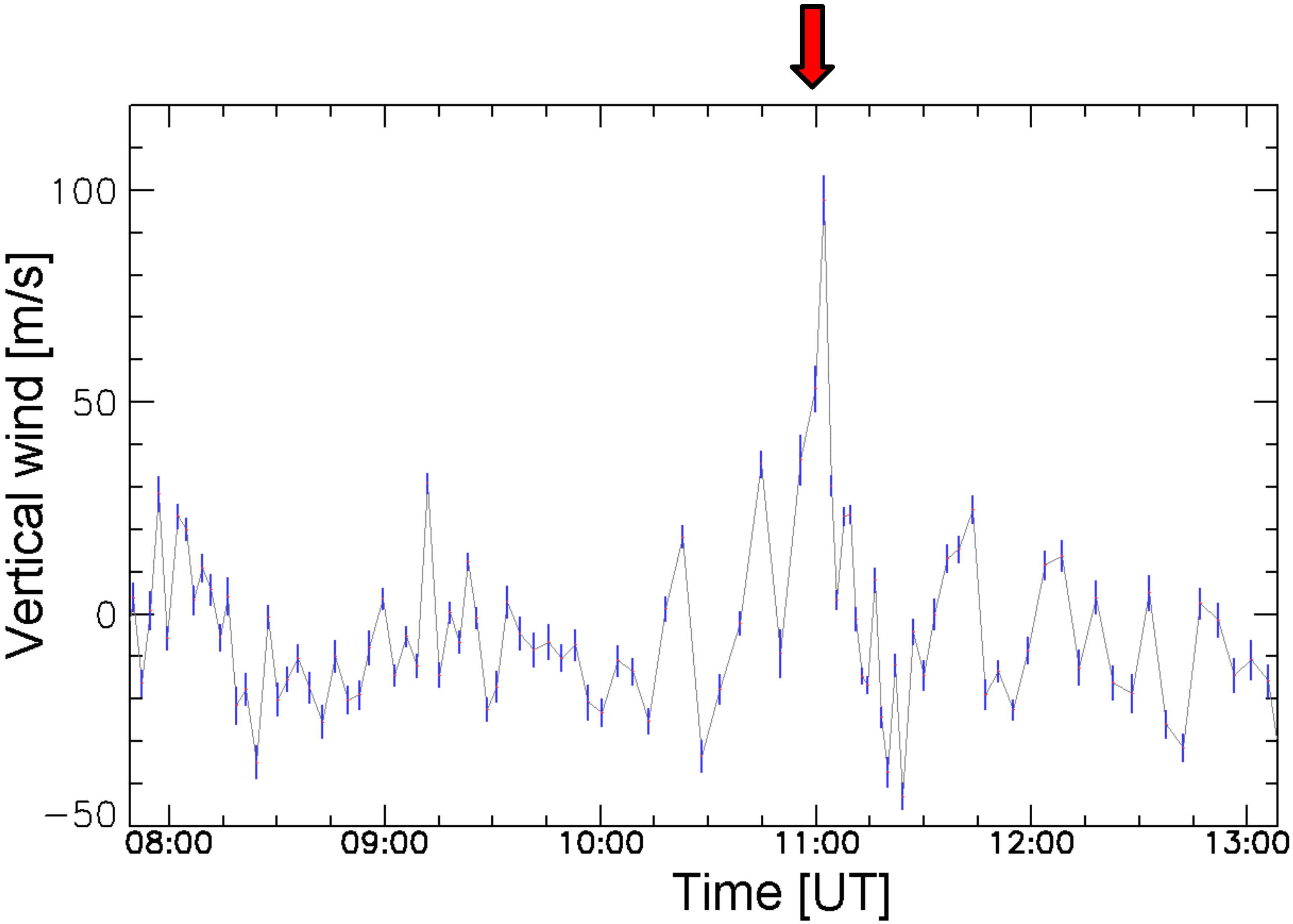
This fit is used to “fill in” the vector components perpendicular to our line-of-sight. In all figures presented here, the line-of-sight components are shown directly as measured.

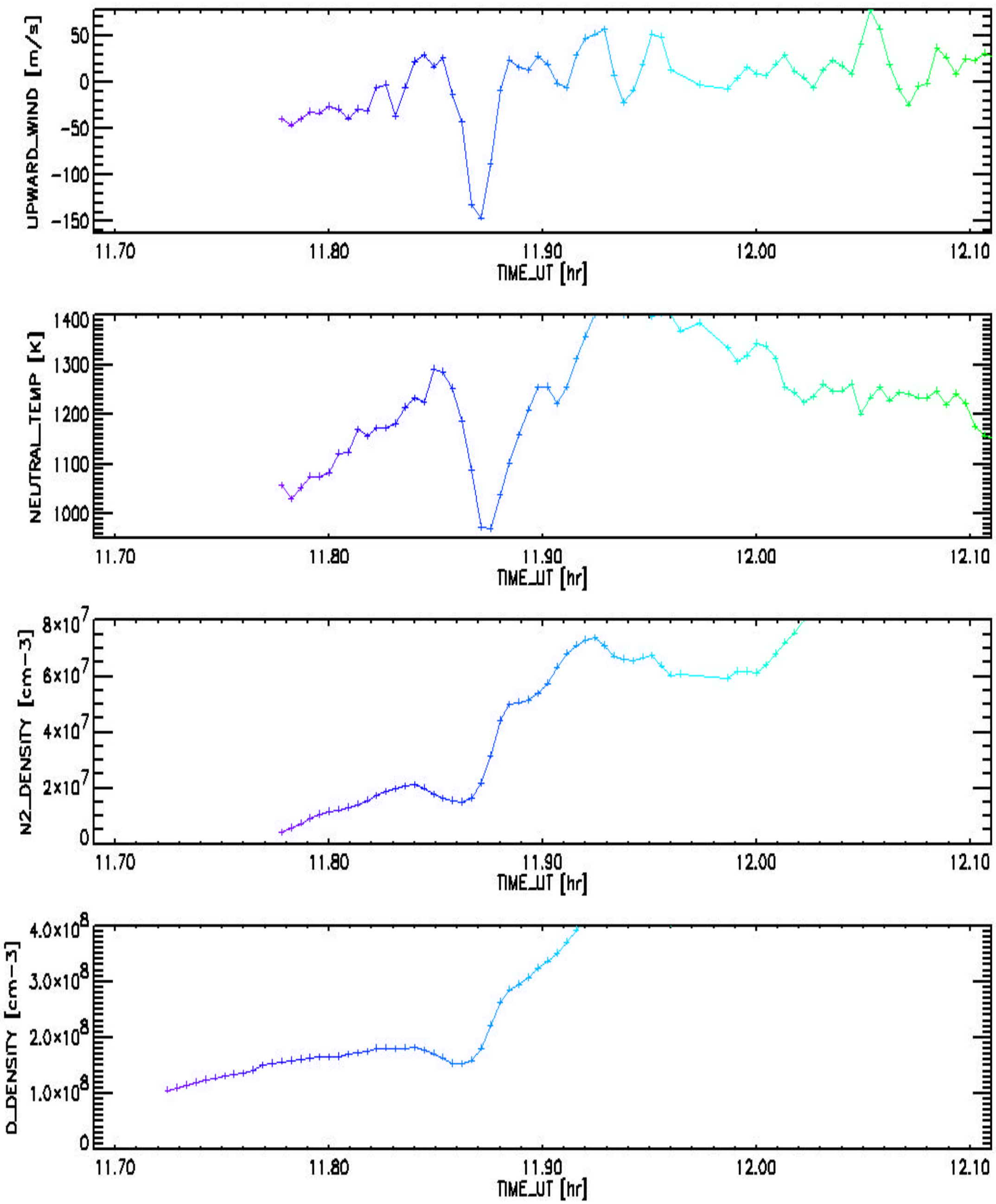
Relating Horizontal & Vertical Winds

Notice the collapse of the horizontal wind ahead of this auroral breakup's poleward expansion. A large upward vertical wind accompanied this event.



Vertical wind above Poker Flat



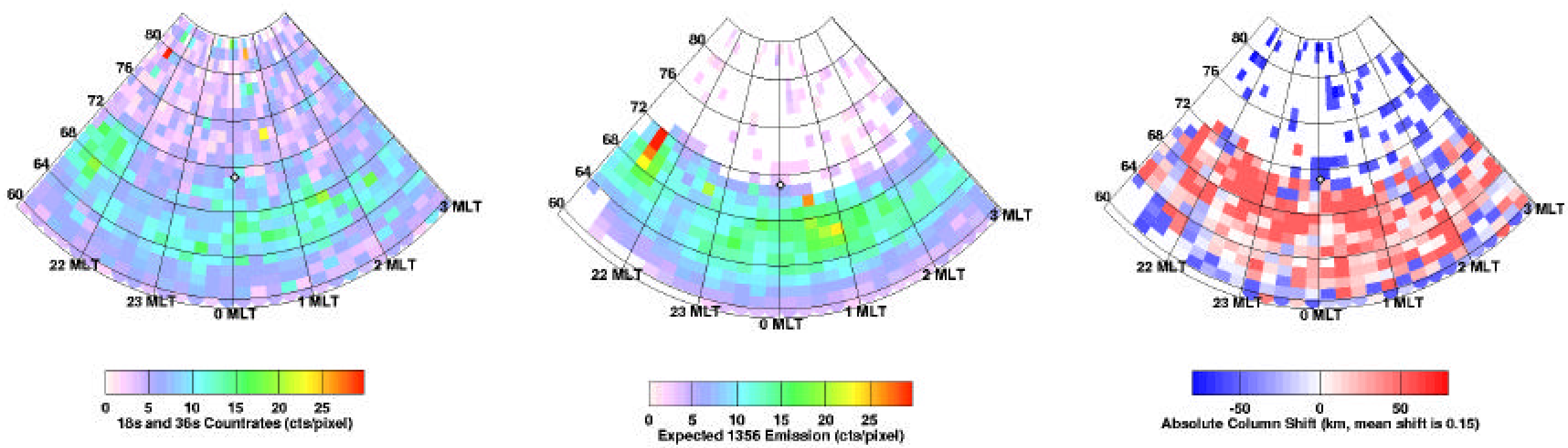


Neutral Atmospheric Perturbations

- This large (>150 m/s) downward wind wind event was observed in-situ by the DE-2 satellite.
- Note the corresponding negative temperature perturbation, negative density perturbations, and positive $[O]/[N_2]$ perturbation.
- What drove this downward wind event?

Vertical Winds & Composition

- The left panel shows an observed λ1356A oxygen image recorded by the Polar-UVI instrument.
- The center panel shows the expected λ1356A emission, based on auroral characteristic energy and energy flux maps (derived from LBHL and LBHS images) applied to an MSIS atmosphere.
- The right panel shows the “column shift” needed in the MSIS model to make observed image =expected image. Presumably, such a column shift would arise due to vertical winds.

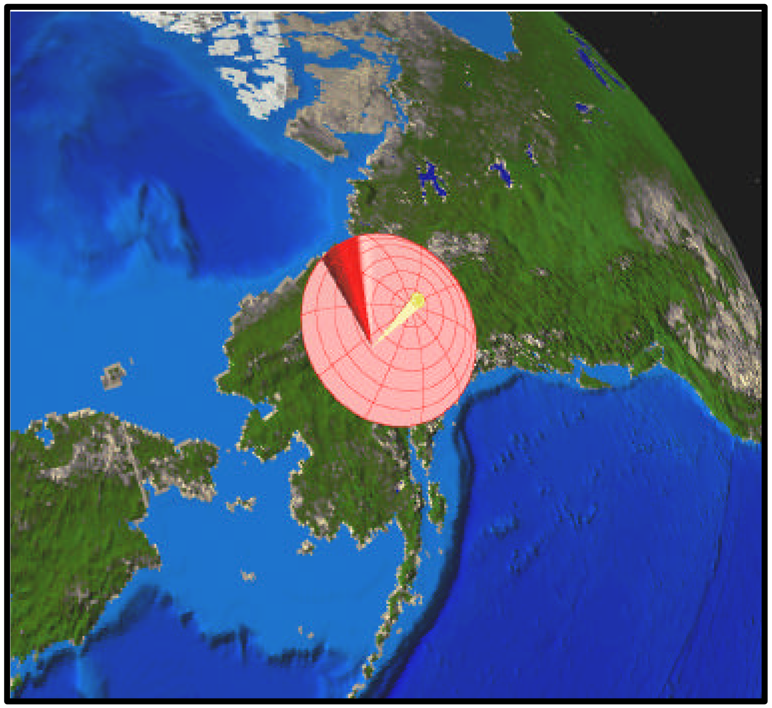


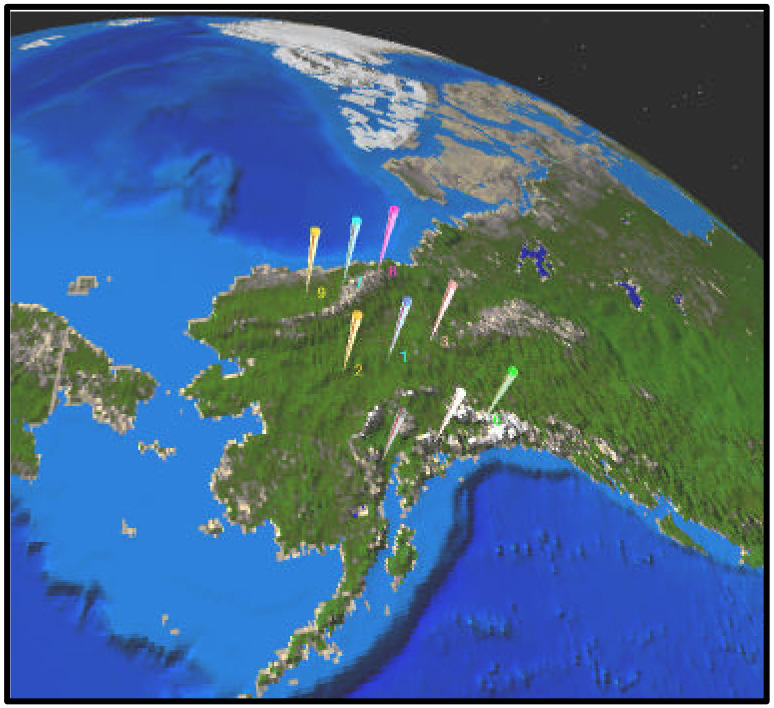
The Problem

- Vertical wind "events" are accompanied by perturbations to the horizontal wind field and to the atmospheric composition.
- Measuring the 3-dimensional flow geometry simultaneously in all 3 velocity components is essential if we are to understand the air parcel trajectories and histories responsible for the puzzling DE-2 WATS/NACS observations shown earlier.
- A single Doppler spectrometer can only measure one flow component, i.e., the component that is aligned along the instrument's line-of-sight.

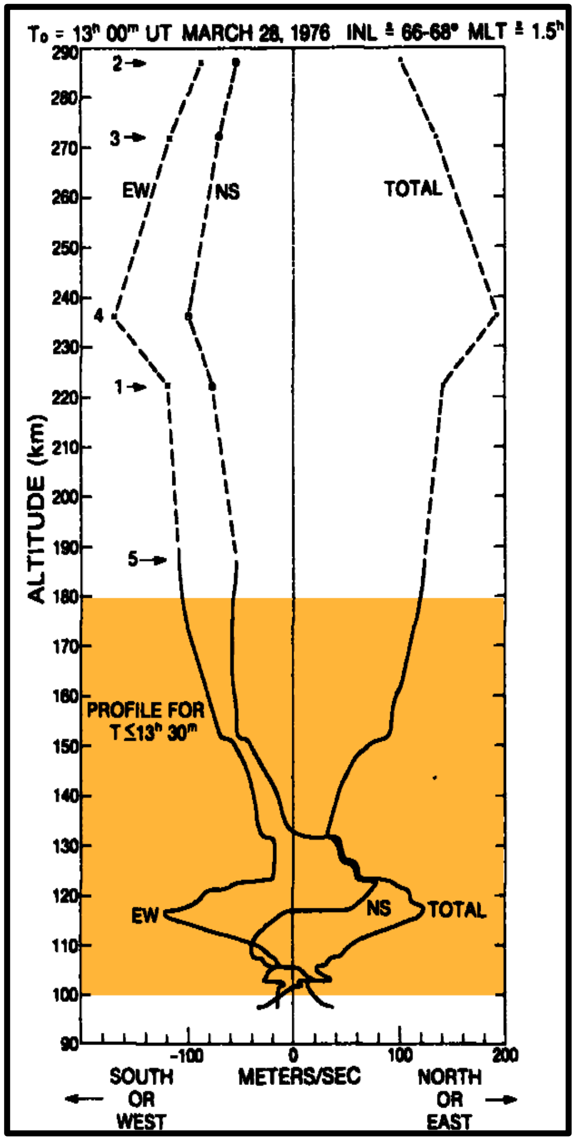
Multi-Station Measurements

- Two separated observing sites allow two velocity components to be determined independently.
- By contrast, a large number of stations with multiply-overlapping "beams" could reconstruct the full 3-component flow field over 2 horizontal dimensions (within the region of overlap).
- However, even a large array cannot map altitude variations (easily). The observations are still limited by the height profile of the emission source.





E-Region Observations are Needed

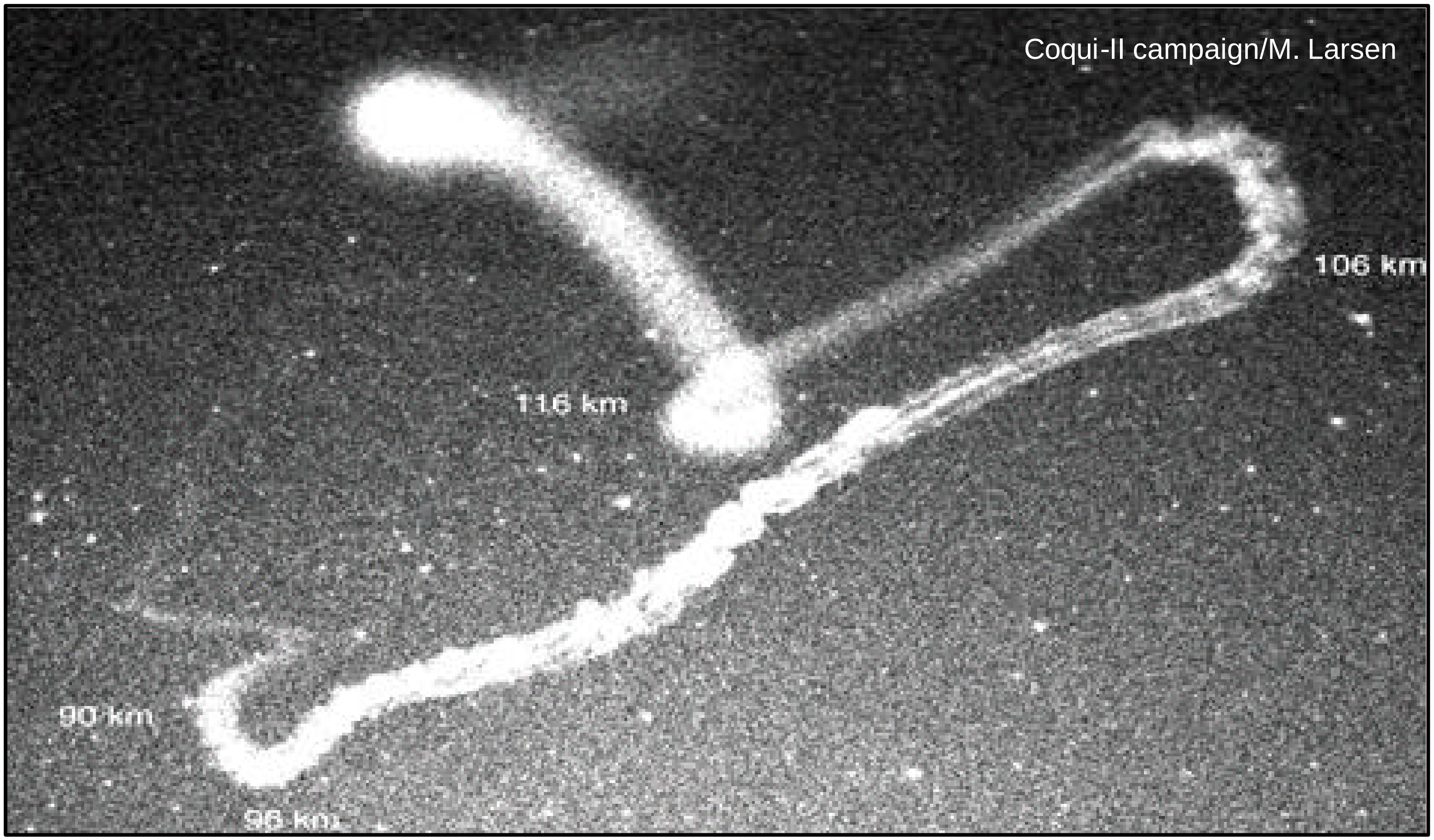


CEDAR Phase III Report, 1997:

- In polar regions, neutral winds and their dynamical feedback create a complicated chain of cause and effect with other aeronomic processes that is presently not well understood.
- This is <u>especially true in the E region</u>. In this altitude regime, the neutral dynamics are strongly influenced by electric fields of magnetospheric origin, pressure gradients established by Joule and particle heating, and momentum forcing by waves.
- These sources of momentum and heat vary with spatial and temporal scales beyond those currently achieved in coupled ionosphere-thermosphere models; moreover, observations are sparse, especially over the polar cap.
- Limited data bases of polar E-region wind measurements show the winds to be quite variable.
- The development of promising instrumentation or techniques for acquiring measurements from the much-neglected 100 to 170-km region should be especially encouraged.

Rocket-released chemical tracers

Ground-based optical remote sensors can observe light generated by a chemical tracer released by a rocket. The tracer can either be chemiluminescent (as in the TMA trail here) or can scatter ambient sunlight.



The daytime problem

- During the day, airglow and auroral emissions are seen from the ground superimposed upon a background of scattered sunlight which, to first order, exhibits the same spectrum as direct sunlight (top panel).
- For example, the λ630-nm dayglow feature appears superimposed on a corresponding Fraunhofer absorption line, but with only about 1% to 2% of the brightness of the solar continuum (middle panel). Note that the λ630-nm Fraunhofer line is gravitationally red-shifted relative to the airglow line. (Wavelength decreases to the right in the lower two panels.)
- Daytime aurora is much more prominent (bottom figure).